FIRST APPROACH TO THE INTERVENTION OF THE PALEOICHNOLOGICAL HERITAGE ON *LA VIRGEN DEL CAMPO* SITE. ENCISCO, LA RIOJA (SPAIN).

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RESUMEN: En el presente trabajo. se analiza el estado de conservación del yacimiento paleoicnológico de La Virgen del Campo, situado en Enciso, La Rioja (España). En primer lugar, se realiza una revision bibliográfica y búsqueda de las intervenciones realizadas en el yacimiento y los materiales que se aplicaron. Por otro lado, se realize un studio del estado de conservación y las causas de deterioro y las patologías presentes en el yacimiento. Dichas patologías, se identifican y se asignan a una categoría concreta gracias al glosario del ICOMOS. Por otro lado, se realiza una propuesta de intervención. Esta propuesta de intervención se realiza gracias a la revision bibliográdica y los estudios preliminaries llevados a cabo en el laboratorio. Finalmente, se realiza un studio de los materiales de restauración, especialmente centrado en los diferentes tipos de morteros de cal, testeando la compatiblidad con la piedra del yacimiento en el laboratorio y durante la campaña de campo

PALABRAS CLAVE: Virgen del Campo site, Paleoichnolofical heritage, Paleontology, Ichnites, Enciso (La Rioja, Spain)

English version

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ABSTRACT: In this paper, we analysed the state of conservation of the paleoichnological site of La Virgen del Campo located in Enciso, La Rioja, (Spain). First, a bibliographic review was carried out, researching about the interventions made on the site and the materials applied. We made a conservation study, in which we analysed the causes of deterioration, using different methods, and pathologies. These pathologies are identified and assigned to a defined category according to ICOMOS glossary. In addition, we carried out an intervention proposal. This has been done, thanks to the bibliographic review and the studies that we accomplished at the laboratory. Finally, we made a study of the restoration materials, specially focused on different lime mortars. We tested their suitability with the rock of the site at the laboratory and then during the field season.

KEYWORDS: Virgen del Campo Site, Paleoichnological Heritage, Paleontology, Ichnites, Enciso (La Rioja, Spai

1. INTRODUCTION

The paleontological heritage of La Rioja (Spain) is of great wealth and diversity, presenting an enormous number of sites and paleontological remains. These sites belong to the Early Cretaceous, and their age is between 145 and 113 million years, (Berriasiense – Aptiense) (Pérez-Lorente, 2015). La Rioja stands out for the sites of dinosaur footprints, being one of the regions with the largest number of them in Europe. It contains about ten thousand footprints discovered, although it is estimated that it can hold around twentyfive thousand (Pérez-Lorente, 2015).

One of the main sites of La Rioja, known as La Virgen del Campo (Figure 1), presents various problems in terms of its conservation. This site is highly exposed to environmental deterioration agents (Caro *et al*, 2003).
Due to the site problems and the large number of cracks that the rock has, various restoration works have been carried out in different campaigns over the last 22 years (Díaz-Martínez *et al*, 2010). The tasks performed have been carried out focused on reinforcing the edges of different strata, cleaning sediment and filling the cracks with mortars and silicones (Pérez-Lorente, 2015).

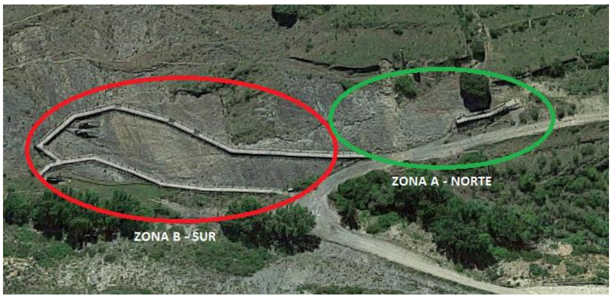

Figure 1. Map of the location of La Virgen del Campo site. Modifand from Google Maps. At this photo, *Zona A- Norte* is the part with crocodile tracks. *Zona B-Sur* is the sculptures' part.

After three years of inactivity, field season resumed in July 2017. Given the state of the site, these campaigns were focused on cleaning the debris accumulated at thesite, as well as other conservation and restoration activities. The objective of this field season was to identify the areas that were potentially more likely to receive damage or deterioration, as well as to carry out those actions that were more necessary for the immediate preservation of the site (Ferrer-Ventura *et al*, 2018). As we resume the field seasons, new lines of research have begun to be developed related to the preventive conservation and maintenance of the La Rioja sites, based on the study of materials that allow us to carry out interventions that are closest to the particularities of La Virgen del Campo site. Thanks to the work done by Caro *et al.* (2003), the materials of the site and previous interventions have been able to be identified, and we have been able to elaborate a rigorous work guide thanks to extensive research work developed by these authors.

The constituent materials of La Virgen del Campo site (Enciso), according to the petrographic study of Caro and Pavia (1998), referred a variety of silica sandstone of fine to medium grain, formed almost entirely by silica in its quartz variety (SiO_2). Sandstone is mostly made of quartz grains and, to a less extent, feldshes and phyllosilicates. There are also scattered iron oxides and opaque ones. The quartz grains are monocrystalline. They have sutured and interpenetrated contacts so that the same grains are cemented by quartz regrowths. The main cement is silica, followed by the phyllosilicates between which Muscovite and clorite predominate. In addition, Caro and Pavia (19998) indicate that the rock has a banded structure, in which they alternate areas with larger quartz with other areas containing smaller quartz and, with other bands, in which oriented phyllosilicates were accumulated. From the petrographic observations it can be determined that the areas formed almost exclusively by quartz grains are compact, coherent and very resistant. On the contrary, the abrupt textural change that implies the transition to areas with phyllosilicates and iron oxides (sedimentary lamination) impairs the durability of the stone, as well as the passage of areas formed by smaller quartz grain size (Caro and Pavia, 1998). Likewise, the site consists of various stratigraphic levels (Figure 2).

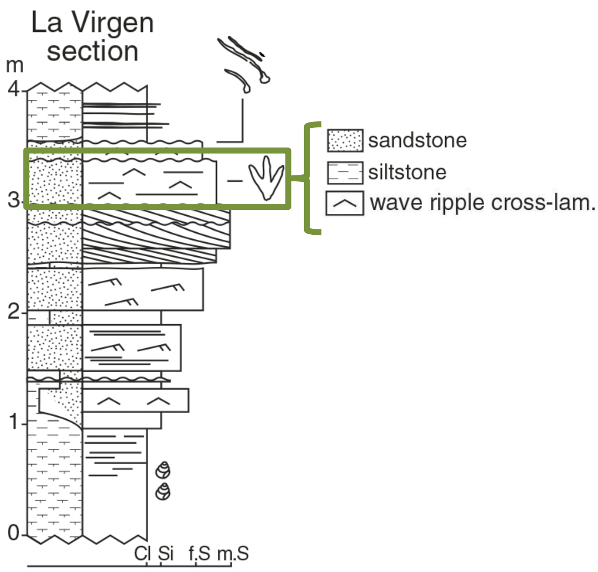

Figure 2. Modified from Ezquerra *et al.* (2007). Stratigraphic column of the site of La Virgen del Campo. In green it is pointed out the section in which the traces of the site are located and, highlights its content in the legend

In order to perform a correct study of the conservation status of the site, the environmental factors and degradation agents/mechanisms, to which the deposit is exposed, must be determined. In this case, sincethe site is exposed to the environment degradation, the factor that most affects its deterioration is water. Water affects stone material in various ways. First, it penetrates into the cracks and fissures. Thanks to the temperature variation, it suffers freeze-thaw cycles creating a wedge effect on such cracks. This creates micro-cracks that contribute to the continuous deterioration of the stone. On the one hand, it allows the water to continue penetrating the rock. On the other hand, it favours the accumulation of deposits and biological colonization. This reveals different pathologies. Therefore, it is necessary to analyse the pathologies and know their origin. Regarding to restoration treatments on stone, there are basic principles that should be considered. First, it will be essential to accomplish a previous research about the materials and methods according to the lithology and environmental conditions of the site (Mas-Barberà, 2006).

Secondly, we pay special attention on the conservation and restoration criteria set out at the *Proyecto Coremans* (2013). They are based on: a) maintaining the interdisciplinary nature of the solutions, b) respecting the material and intangible value of the site, c) solving the problem at its origin, d) ensuring compatibility with conservation, e) making minimal intervention whenever the stability and physical integrity of the site is guaranteed, f) employ compatible and reversible materials, g) promote maintenance, preventive conservation, environmental, economic and human sustainability, h) supply with documentary evidence the entire intervention on the site, and finally, (j) disseminate and promote access to cultural heritage through an informative discourse understandable to society. We accomplish a search to establish the most appropriate materials and methods for the restoration of the site, based on the previous conservation and restoration criteria, considering the function and properties of the mortars and, the environmental conditions.

Martínez Ramírez (1995) points out that mortars are materials used in construction, made by different components, which are arid, conglomerated and water. Cazalla (2002), notes that, the term mortar defines a mixture of a conglomerated (lime, cement, plaster or clays), with an arid and water. Martinez Ramírez (1995) points out that it may contain other additives.

Currently we know different types of mortars with many variants in their components. As Mas-Barberà (2006) indicates, there are mortars based on resins and polymers, such as thermoplastic resins (acrylic, vinyl) and thermosetting (polyester and epoxy); also mixed mortars, which are formed by hydraulic conglomerated with polymers of a thermoplastic nature; in addition, non traditional hydraulic mortars, which includes Portland concrete and, finally, traditional mortars, i.e. lime-based mortars.
Lime mortar is the conglomerated part, i.e. lime itself (calcium hydroxide) (Martínez-Ramírez, 1995). Lime can be aerial, which slowly hardens by the action of atmospheric carbon dioxide. This exposure gives rise to the following reaction:

$$Ca(OH)_2 + CO2_{(g)} \rightarrow CaCO_3 + H_2O$$

On the other hand, hydraulic lime, as Doménech (2013) explains, contains significant amounts of silica and alumina. These materials have hydraulic properties, which means that they can perform the setting process even under water (Doménech, 2013. According to Martínez-Ramírez (1995), although lime mortars have been used since ancient times, their use has declined in favour of other mortars, such as concrete. The recovery of lime mortar is carried out in favour of other specific applications such as heritage restoration. We have an example of this in the following doctoral thesis dedicated to mortars, their study and/or application in heritage: Cazalla, 2002; Mas-Barberà 2006; Igea, 2011; Guash 2016, among others. Cazalla (2002), says that the dosage of the lime mortar will vary depending on its purpose and the type of lime used, either dull or hydraulic. Through the compilation of previous information, we could assess the current conservation status of the paleoichnological site of La Virgen del Campo. This diagnosis provided information of the petrological characteristics and properties of the stone and the previous treatments developed. At the same time, the environmental factors, which the site is exposed, were studied, as well as the agents and mechanisms of deterioration responsible for the damage present on the site. Finally, with the compilation of all the information, a first study of lime mortars was carried out to check their compatibility with the needs of the site and, in this way, reduce the damage to which the site is subjected. As a final challenge, a new intervention strategy has been proposed according to the particularities of the site.

2. METODOLOGY

For the study of the characteristics and the current state of conservation of the site has been necessary to accomplish various visual analyses, photographic records and laboratory data, as well as the specific bibliographic review in primary and secondary sources. These observations and analyses have been essential for the study of the properties of the materials that constitute the site and for the diagnosis of its current conservation status.
As mentioned above, in this study, we adapt the principles of conservation and restoration of stone materials, established in the Proyecto Coremans (2013), to paleoichnology. Taking into account the above intervention criteria, the global areas of research are also adapted: a) Study of heritage (Significance, identification and monitoring of possible movements and characterization of materials), b) Study of the environment (Environmental conditions, natural and anthropic environment), c) Study of the conservation state (Preliminary examination, characterization of material degradation, pathologies, biodeterioration and humidity) and, d) approach to the intervention on site.

2.1. Materials belonging to the site

In order to know the nature of the material to be intervened, a bibliographic research of the many studies carried out in the Virgen del Campo site has been made. The works of Caro and Pavia (1998) and that of Hernán (2018) stand out. Also, in order to determine the state of the stone of the site with respect to the state of the healthy rock, a comparative water test of water absorption was performed by the pipette method (UNE EN 16302:2013). To do this, rock belonging to the same section of the study object was extracted from the surrounding of the site. We analysed the amount of water absorbed by the stone, controlling the stone absorption over a period, so that it can be extrapolated to the study of stone of the site. It is important to know and control the amount of water in contact with the stone due to its deteriorating power for various reasons (rain, capillary ascent, runoff, transport of soluble salts and contaminants, among others).

2.2. Environmental conditions monitoring

The monitoring of the environmental conditions were performed using a datalogger device (Inkbird ® IBSTH1), which measures temperature and relative humidity using a contact probe. The datalogger is configured using Inkbird Tech C.L., free Engbird app available on both Android and iPhone stores. The device was configured to take data every 30 minutes. This data was collected via Bluetooth connection and synchronization with the app.

2.3. Conservation state and diagnosis

A visual analysis was carried out *in situ* and allowed to determine the main pathologies of the site. A damage map accompanied this analysis, where we located the main pathologies in space for further analysis. In addition, a scheme (Figure 3) was made with the main causes of deterioration, found in the site.

This scheme is used to identify the pathologies and its possible origin. Once the above steps were performed, the pathologies were identified through visual and photographic analysis that directly shows the conservation status of the site.

For greater clarity in the technical language of the terms, the glossary of ICOMOS-ISCS: Illustrated Glossary on Stone Deterioration Patterns (2010), define: a) alteration as a modification of the material that does not necessarily imply a worsening of its characteristics from the point of view of conservation. For instance, a reversible coating applied on a stone may be considered as an alteration; b) damage as the human perception of the loss of value due to decay; c) decay as any chemical or physical modification of the intrinsic stone properties leading to a loss of value or to the impairment of use; d) degradation, as a decline in condition, quality, or functional capacity; e) a process of making or becoming worse or lower in quality, value, character, among others; and, f) weathering as any chemical or mechanical process by which stones exposed to the weather undergo changes in properties and deteriorate.

2.4. Approach to intervention strategies

In this section, two phases have been developed: 1) previous preparation of mortars and, 2) treatment in situ on the site. In order to know the materials of intervention, a first search is made on the lime mortars, its use and study for the restoration of stone heritage.As a preliminary test to determine the main behavioural characteristics of lime mortars and their most commonly used dosages (Cazalla, 2002), it was carried out in the laboratory. The different components of the mortars were weighed and mixed dry to finally add the corresponding water. Once the mixture was ready, we introduced it into 4cm3 silicone molds for one week. Subsequently, they were demolded, and reanalyzed with the pipette method (UNE EN 16302:2013).

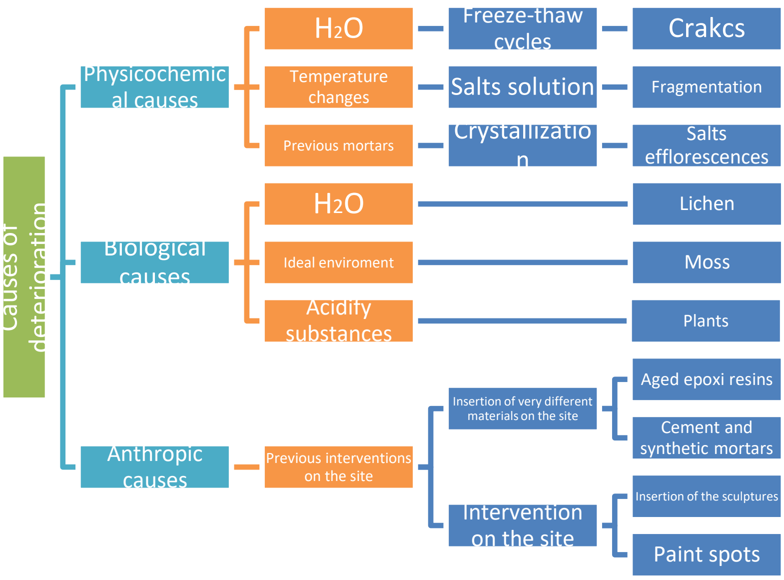

Figure 3. Scheme that reflects the causes, agents, deterioration mechanisms along with the deteriorations they produce.

In another order of organoleptic analysis, mortars were also applied on natural rock samples to verify their adhesion, integration, suitability and reversibility. Finally, the mortars were also tested in the environment of the site to observe their response to environmental agents. Regarding to the treatment in situ, in this case, only a mechanical and superficial cleaning of the deposit has been carried out by means of brushes, brushes, and incision elements such as scalpels. Following the above analyses, the areas with deeper cracks are consolidated by means of mortar injection, using syringes. In the case of areas with more superficial losses or less deep cracks, volumetric reintegration is carried out using lime mortar and application with a spatula. The protective measures are under study since, as protection measures, the application of a water repellent has been tested, applied to tracks affected by water accumulation. The effectiveness of this water repellent is tested in each field campaign to check its condition and the possibility of a colour variation. The product is Tecnadis AQUAPORE FORTE ®, silica-based water repellent. This is controlled by in situ testing and photographic monitoring of the area.

3. RESULTS

The lack of specific intervention criteria in paleoichnological heritage made that we adapted the *Coremans* stone intervention criteria, proposing a new intervention strategy focused on: a) study of the material belonging to the site, b) environmental conditions monitoring, c) conservation state and diagnosis and, d) approach to intervention strategies.

3.1. Environmental conditions monitoring

A datalogger is installed in the most deteriorated area to specifically monitor the conditions of the particular site. On the other hand, in Figure 4, data taken from February 4_{th} to July 30_{th} of 2019 can be seen with a total of 8416 measurements. In the graph below, on the left, temperature intervals in Celsius degrees can be observed in the X axis, and the times the measurement has been taken can be observed on the Y axis. Temperatures mostly fluctuate between 4.39 $_{o}$C and 14.79 $_{o}$C with a total of 4351 measurements in the represented interval, representing 51.70 % of the total. Futhermore, the minimum temperature recorded is 0.91$_{o}$C and the maximum is 35.63$_{o}$C, with variations of more than 10 $_{o}$C in the same day. As for the graph on the right, it refers to relative humidity. On the X axis, the interval of the percentage of relative humidity can be observed and on the Y axis it can be observed how many times that interval has been registered during the mentioned time period. In this case, 3127 measurements of more than 91.51 % relative humidity have been registered, representing 37.15 % of the total measurements. Secondly, data that shows a humidity greater than 82.92 % humidity (the last two intervals) comprises 4174 measurements, representing 49.59 % of the total measurements. As for the lowest relative humidity is 14.25 %, while the highest is 100 %.

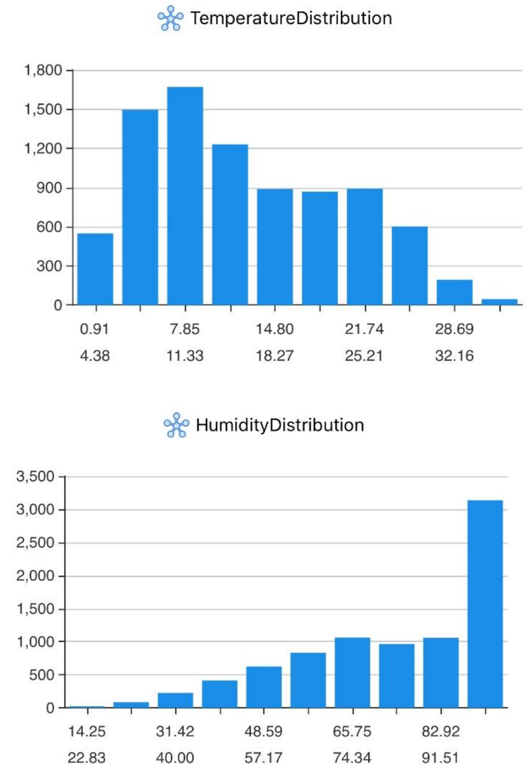

Figure 4. Examples graphics of the datalogger data. These show the temperature and relative humidity variation. It shows how many times these intervals of temperature and relative humidity occurred between the 4th of February and the 30th of July. Y-axis shows how many times this interval appears. At X-axis, we can see the interval.

3.2. Conservation state and diagnosis

The degradation agents that produce majority of the damage to the site are: water, erosion, and the ice-thaw effect, these agents can be seen in Figure 3, using the visual indicators for identifying damage proposed by ICOMOS-ISCS Glossary Reference Guide: Illustrated Glossary on Stone Deterioration Patterns (2010), based on the description of forms of deterioration that can be seen with the naked eye. According to the identification of the damage present at the site using the ICOMOS-ISCS Glossary Reference Guide (2010), the pathologies found in the site of La Virgen del campo are listed below.

1) Crack (Fracture, Hair crack, Splitting): Fissure, clearly visible by the naked eye, resulting from separation of one part from another of the stone (Figure 5).

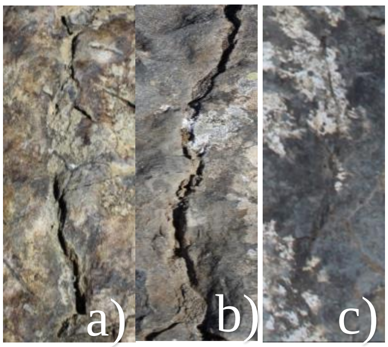

Figure 5 (a-c). Different kind of cracks. a) Fracture, crack that crosses completely the stone piece; b) Hair crack, minor crack with width dimension < 0.1 mm; c) Splitting, fracturing of a stone along plans of weakness such as microcracks or clay/silt layers, in cases where the structural elements are orientated vertically. For instance, a column may split into several parts along bedding plans if the load above it is too high.

2) Splitting: Fractured stone long plans of weakness such as microcracks or clay/silt layers, sometimes where the structural parts are orientated vertically. For example, a column may split into a lot of parts along plans if the load above it is too high (Figure 6).

Figure 6. Splitting example from the site.

3) Delamination: Detachment process affects the laminated stones (especially of sedimentary rocks, and some metamorphic stones). This corresponds to a physical separation into one or few layers following the laminated stone. The density and the shape of the layers are changeable. (Figure 7).

Figure 7. Delamination example from the site.

5) Fragmentation: Complete or partial scatter of the rock, into portions of variable size, that are irregular in form, density and volume (Figure 8).

Figure 8. Fragmentation example from the site

6) Erosion (Differential erosion): Loss of original surface, leading to smoothed shapes. (Figure 9)

Figure 9. Differential erosion occurs when erosion does not proceed at the same rate from one area of the stone to the other. As a result, the stone deteriorates irregularly.

7) Missing part: Empty space, without contents located in the place of some formely current stone part.
Come through and particularly exposed parts are normal location for material loss (Figure 10).

Figure 10. An example of a missing part. In yellow is located a missing part in a footprint.

8) Crust: Usually consistent accumulation of materials on the surface of the rock. A crust may include exogenic accumulation in combination with other materials derived from the stone. (Figure 11).

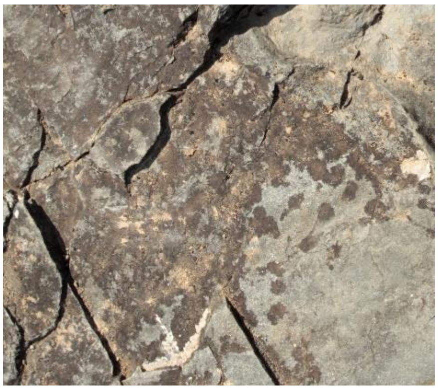

Figure 11. Crust example from the site.

9) Deposits: Accumulation of exogenic material of variable density. For example: splashes of paint or mortar, atmospheric particles such as soot or dust, remains of conservation materials, blast materials, etc (Figure 12).

Figure 12. Deposit example from the site. It has, essentially, clay, small rocks and sand.

9) Efflorescence: Generally whitish, powdery or whisker-like crystals on the surface. Efflorescences are generally poorly cohesive and commonly made of soluble salt crystals (Figure 13).

Figure 13. Efflorescence example from the site

11) Biological colonization (Lichen, moss, plant): Colonization of the stone by plants and micro-organisms such as moss, lichen, algae, and lichen (symbioses of the latter three). Biological colonization also includes influences by other organisms such as animals nesting on and in stone. (Figure 14).

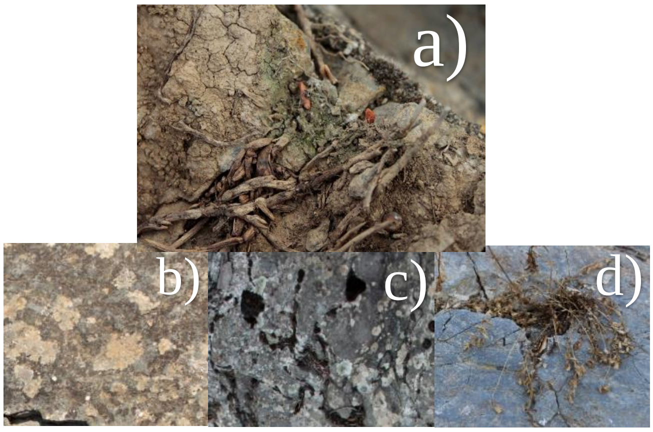

Figure 14. (a-d) a) Different kinds of biological colonization. b) Lichen, vegetable organism forming rounded millimetric to centimetric crusty or bushy patches, often having a leathery appearance, growing generally on outside parts of the stone. Lichen are most commonly grey, yellow, orange, green or black and show no differentiation into stem, root and leaf. c) Moss, vegetable organism forming small, soft and cushion greens of centimetric size. Mosses look generally like dense micro-leaves (sub- to millimetric size) tightly packed together. Mosses often grow on stone surface open cavities, cracks, and in any place permanently or frequently wet (masonry joints), and usually shady. d) Plant, plant living being, having, when complete, root, stem, and leaves, though consisting sometimes only of a single leafy expansion (e.g. tree, fern, herb).

The main pathologies are located on a map or sketch of damage. Each area of the site affected by one or more of the above damages is indicated and differentiated on the map by the accompanied legend in the image. The result of that mapping can be seen in Figure 15.

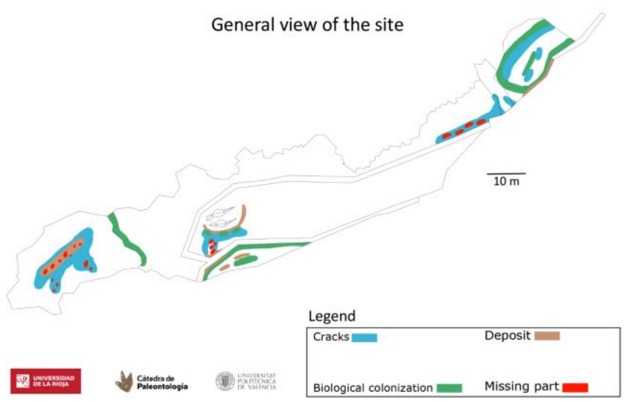

Figure 15. Damage map. Aerial view of the site. At the right part is the crocodile site. At the left part of the map, you can see the sculpture's part of the site. The legend shows the colours of the main damages of the site, which are coloured in it.

In the image above, the amount of damage such as cracks, fractures, sediment accumulations, splitting and delamination mainly can be seen. In turn, the site has loss of parts, followed by the large biological colonization, mainly lichens and mosses. It also contains the presence of plants, both inferior and superior. All other damages were located in more specific areas.

3.4. Approach to intervention strategies

The results of organoleptic observation during the preparation of lime mortar specimens show a clear difference in their homogeneity, workability and plasticity. Differences in the conglomerating relationship and load in the mortar manifest differences in its behaviour. The 1:1 dosing mortars (Sánchez, 2002) have a great homogeneity. Dosage 1:2 (Cazalla, 2002) presents some homogeneity. Finally, the mortars with the 1:3 dosage used in heritage and mentioned by Cazalla (2002) and Sánchez (2002), presents, a greater textural heterogeneity.

Finally, a natural hydraulic lime 3.5 (NHL, UNE-EN 459-1:2016) from Saint Astier was chosen, discarding the NHL 5 lime for its greater mechanical performance and the NHL 2 for its whiteness. Natural hydraulic lime 3.5 has a great plasticity, due to the clay content of the limestone from which it comes, but it is hard enough to withstand compressions. This lime was used in different proportions, together with aggregates of different natures, checking the characteristics of the resulting mortar, both for its surface texture, the mode of application and its mechanical properties. In this sense, a set of different mortars composed of natural hydraulic lime 3.5 and, load of silica sand (size less than 2 mm), was made, in proportions 1:1; 1:2and, 1:3 (lime : arid, respectively). Also, natural hydraulic lime mortars 3.5 and, calcium carbonate load (size less than 0.3 mm) were made in a 1:5 ratio to allow injection into microfissures and cracks. Regarding to the results treatments in situ, the monitoring of the localised water repellent application after one year, no colour variation has been observed. No loss of effectiveness of the product has been observed, as it continues to work. In addition, the area where this material has been applied showed almost no plant growth compared to the previous two years.

4. DISCUSSION

Paleoichnological conservation and restoration needs to be subject to intervention criteria, also to providing scientific information. Heritage is subject to common and standardized intervention criteria. For this reason, the *Proyecto Coremans* criteria for the intervention of stone material are evaluated and adapted. This intervention guide will set the general guidelines for preserving the heritage in all its facets, tangible and intangible. For this reason, the global areas of intervention are taken as references, and subsequently the proposed script for the new intervention proposals is drawn from them.
The outcome of this research is to establish new intervention strategies and standardized them.

4.1. Material belonging to the site

As mentioned above, Caro & Pavia (1998) point out that the layers containing footprints of the La Virgen del Campo site are formed by a variety of silica sandstone of fine to medium grain, formed almost entirely by silica in its quartz variety (SiO 2).This same information is ratified by Hernan (2018), when he mentions the levels contained in both dinosaur tracks and crocodile tracks.

4.2. Environmental conditions monitoring

Related to the monitoring of the site, in the case of temperature, we can notice a bias towards to the colder temperatures. Since the data comprise the interval between 4th February and 30th July, and data of a complete year are not available yet, this shift on the temperature cannot be determining. To have the complete data of the temperature ranges it would be necessary to have the complete year to check for any displacement. On the other hand, in the case of humidity, although we do not have full year data (since it comprises the same interval as the temperature), we appreciated that almost half of the measurements taken represent a relative humidity larger than 82.92 %, and we can see a clearer graphic than the temperature one. With this information, we can infer that the relative humidity in the most affected area of the site is quite high, although, to ensure this, same analysis should be performed with the entire data. Once we have all the data from a year we will be able to ensure how the environmental conditions affect their conservation status. In addition, water is the main degradation agent on the site, leading the analysis and identification of pathologies, being the origin of these. As can be seen, the most abundant pathologies are cracks, fractures, delamination and exfoliation. This is due to water access and the freeze-thaw effect, which creates microfissures and causes progressive material loss. Furthermore, temperature variations of 10 oC over a 24h period, coupled with a large continuous humidity in the site, it could contribute strongly to the production of the identified pathologies.

According to Fort (2005), a high presence of humidity in the stone decreases its mechanical properties for different reasons, such as ease of biological colonization, chemical degradation and favouring ice crystallization processes. In addition, Fort (2008) notes that stones that are in contact with such humidity and have little evaporation capacity, can potentially suffer degradation processes by action of the freezethaw effect, if the external temperatures are low. As we have seen, the humidity in the site remains high, indicating that this process could occur with the temperature variation. Therefore, evaluating the damage to improve the conservation of the site will be done by evaluating where the humidity comes, where it remains and how much to avoid it as much as possible. Correlating the data taken from environmental conditions, the analysis of causes, mechanisms and agents of deterioration, and pathologies, together with the elaboration of damage maps, you can evaluate the conservation status and actions priority at the site. Thanks to all this data, decision-making for the intervention in the site is more according to your needs. In this way, the action can be performed directly by attacking the origin of the damage, preventing its appearance. In addition, knowing how important water is in the process of degradation of the site, together with monitoring of the most affected area allows it to be better correlated.

4.3. Conservation state and diagnosis

One of the most significant damages present in the site of La Virgen del Campo and, which aggravates its state of conservation, is the presence of microfissures, cracks and ruptures in the stone stratum of ichnitas. The presence of materials from previous interventions (filling and rejoining materials) was also observed to impair the stability of the whole and increase the formation of new cracks and losses. In addition, water is the main degradation agent on the site being the origin of these damages.

4.4. Approach to the intervention

In the present case, the presence of cracks increases the loss of material in the site. The sealing and filling of the cracks is chosen in order to solve such damage. For the treatment of filling, as mentioned above, the recovery of lime mortar widely used in the restoration of stone heritage is chosen.
Given the environmental conditions of the site, with high humidity, and in which the mortar is to be applied; the hydraulic lime has the ideal setting properties. For the same reason, mortars are made with dosages 1:1, 1:2 and 1:3, which are commonly used in restoration (Cazalla 2002). Of the organoleptic results of the mortars, and the known properties of these (Martínez-Ramírez 1995; Cazalla, 2002; Sánchez, 2002 and Mas-Barberà, 2006), dosages were chosen to perform the sealing of the cracks with a 1:2 dosing mortar. To perform the mortar injection into deeper cracks, 1:5 mortar with marble powder was chosen as it was necessary for the particle size of the arid to be smaller to facilitate both handling and filling.

The need for intervention on paleoichnological heritage, and the lack of studies of these mortars in palaeontology, opens a research line within the conservation and restoration of paleoichnological heritage.The mechanical cleaning has allowed a better vision of the state of conservation of the deposit and the identification of some of the pathologies hidden under the accumulated soil deposits. The cleaning of the deposit also leads to better maintenance of the deposit itself, avoiding the proliferation of plants in the short term.The volumetric consolidation and reintegration work carried out at the La Virgen del Campo site hasprovided stability to parts that were at serious risk of loss. In addition, they make it easier to read sometraces that were very deteriorated, showing some of these traces more clearly. On the other hand, it is necessary to carry out a more accurate study of the characteristics of the mortars in order to better adjust these materials to those of the site.

4.5. Protective measures

Related to the protective measures for the site, various options are being considered. We were monitoring the environmental conditions of the site since 4th february 2019, when the full annuity is obtained and changes are observed, upwards and downwards, plus the contribution of humidity, the different materials can be studied in relation to the conditions they will endure in situ. At this moment, a water repellent has been applied in the areas that were at high risk of loss, thus mitigating the loss until more complete studies are carried out in the future.

5. CONCLUSIONS

The most important conclusions of the work relate to:

a) The comprehensive study of the site (environmental conditions, causes, mechanisms and agents of deterioration and the location and identification of pathologies), allows to know more accurately what the state of conservation and the origin of the damage is suffered by the site. The incorporation of new strategies in the intervention on paleoichnological heritage helps to carry out a comprehensive evaluation of the deposit.
b) Based on previous work carried out by Caro et al. (2003) on the site and, during previous laboratory studies, have provided 1) necessary and valuable information for knowledge of the constituent material, 2) assess the conservation status of the site and, 3) to examine the selected materials.

c) The use of traditional lime mortars during the treatment of seals and/or together in paleoichnological heritage, widely used these materials and techniques in architectural and sculptural-ornamental stone heritage. This allows to open a field of study for the research and intervention of these materials applied to footprint sites.

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